Improved Back Reflector for High Efficiency Hydrogenated Amorphous and Nanocrystalline Silicon Based Solar Cells

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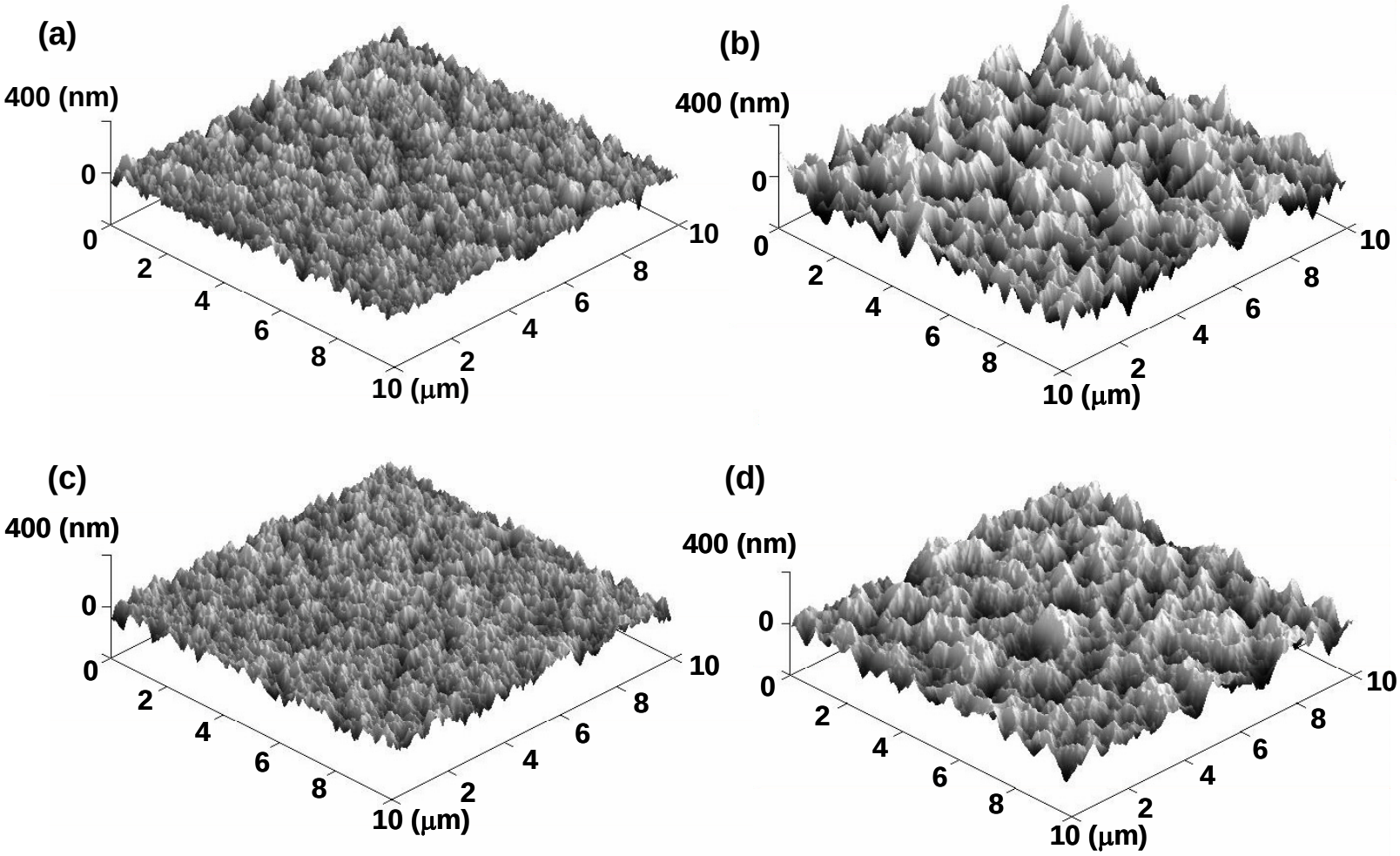
INTRODUCTION AND MOTIVATION

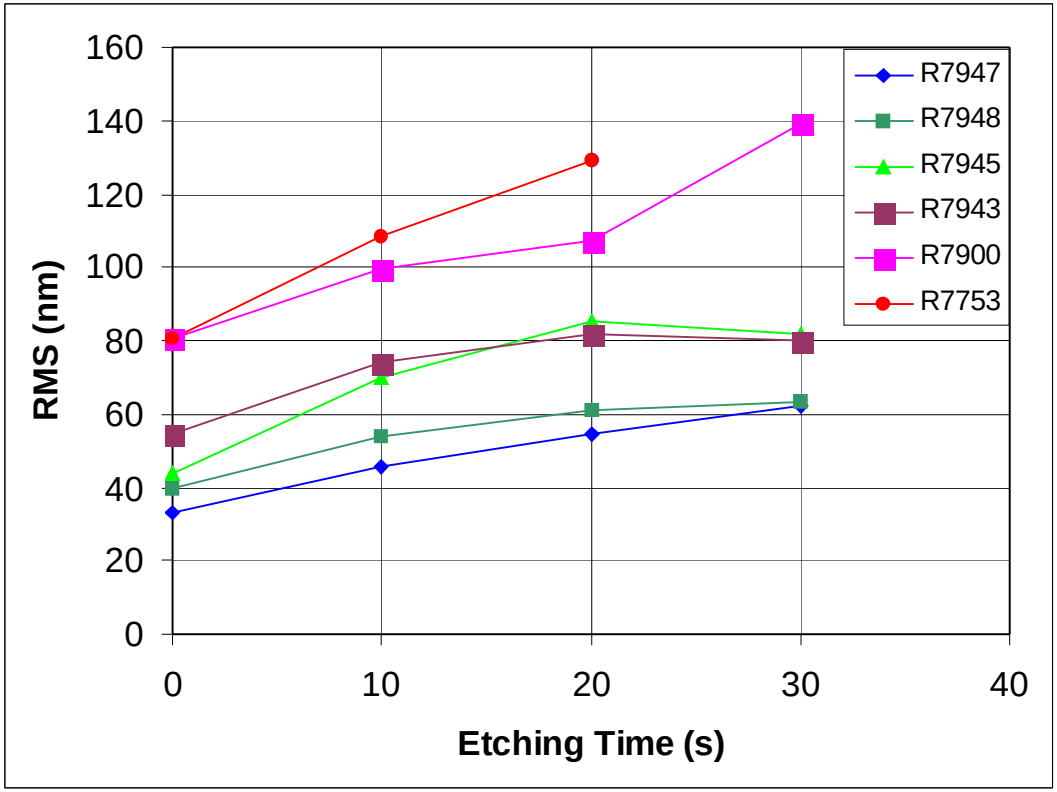
1. Light trapping with textured BR is an important method for enhancing J_{sc}.
2. A textured Ag/ZnO BR was used for achieving 14.6% initial and 13.0% stable efficiencies using an a-Si:H/a-SiGe:H/a-SiGe:H triple-junction structure.
3. nc-Si:H solar cell has attracted remarkable attention. The optimized Ag/ZnO BR used for the a-SiGe:H solar cells may not necessarily be the best choice for the nc-Si:H solar cells.
4. An improved BR may result in an even higher efficiency for a-Si:H/a-SiGe:H/a-SiGe:H.

Experimental

1. Ag/ZnO BR deposition: Sputtering method
2. Chemical etching: 0.5% HCl
3. Surface morphology measurement: AFM at NREL
4. Light scattering measurement: He-Ne laser, measure the scattered light at different angles
5. Solar cell qualification: a-SiGe:H single-junction, nc-Si:H single-junction, and a-Si:H/a-SiGe:H/nc-Si:H triple-junction cells made using RF glow discharge

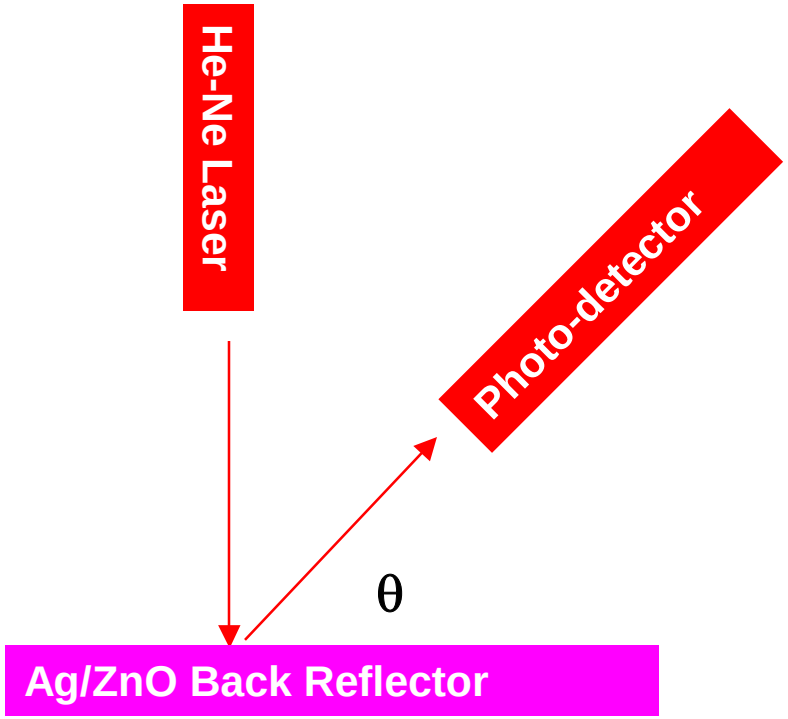


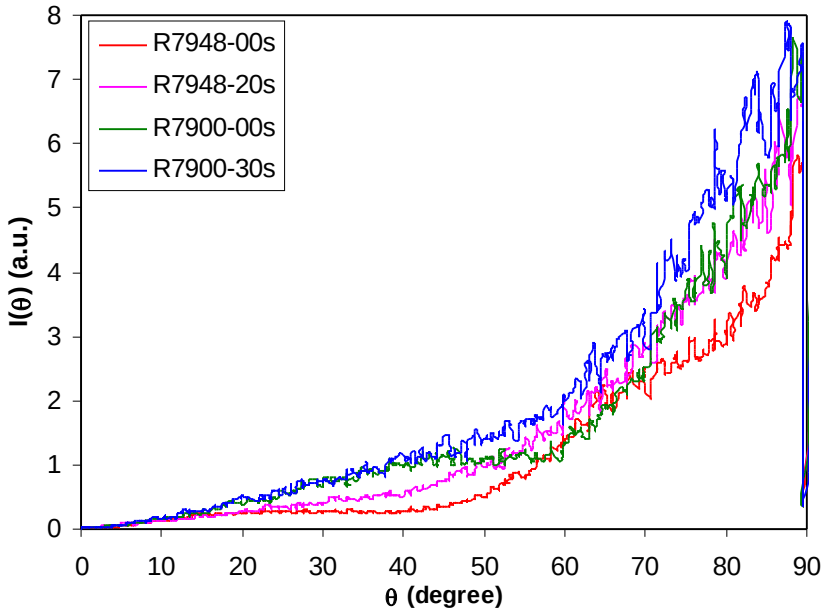
AFM pictures of (a) 5BR1743, (b) R7700-00s, (c) R7948-00s, (d) R7948-30s

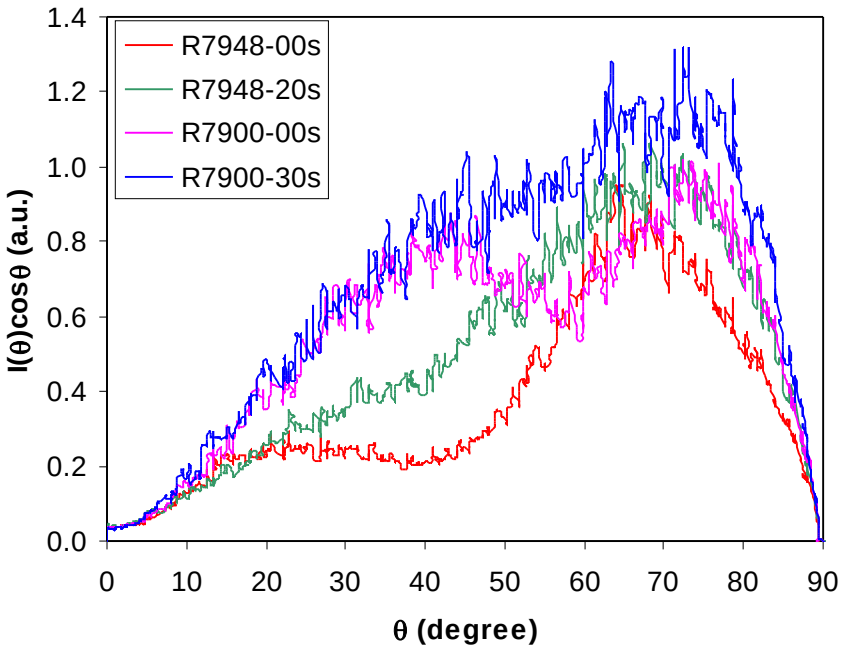


RMS versus etching time in 0.5% HCl

Light scattering measurement setup







Scattered light intensity I(θ) and I(θ)cos(θ) versus θ for two Ag/ZnO BRs before and after chemical etching..

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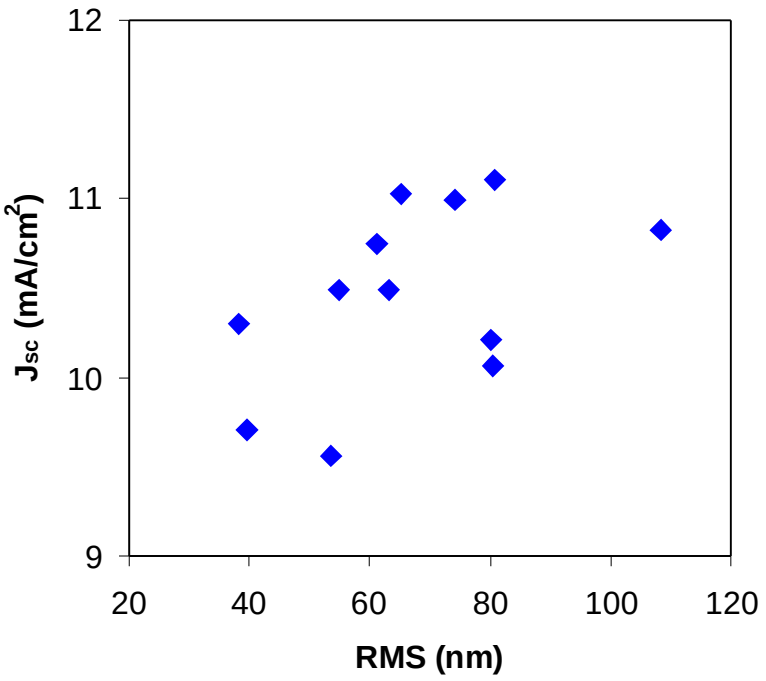
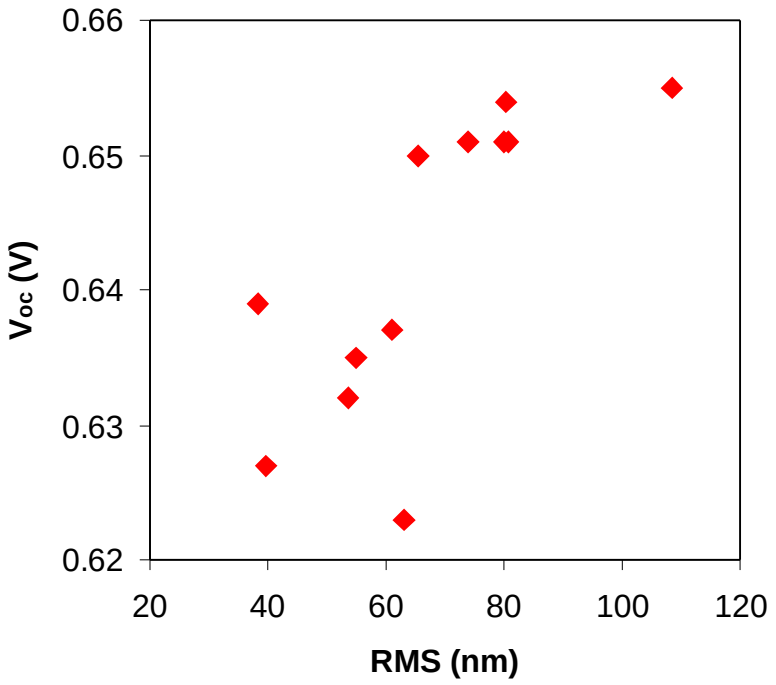
a-SiGe:H solar cells

Table I. BR properties and a-SiGe:H alloy solar cell performance. The J-V characteristics were measured under an AM1.5 solar simulator with a 630-nm long pass filter with J_{sc} obtained from QE .

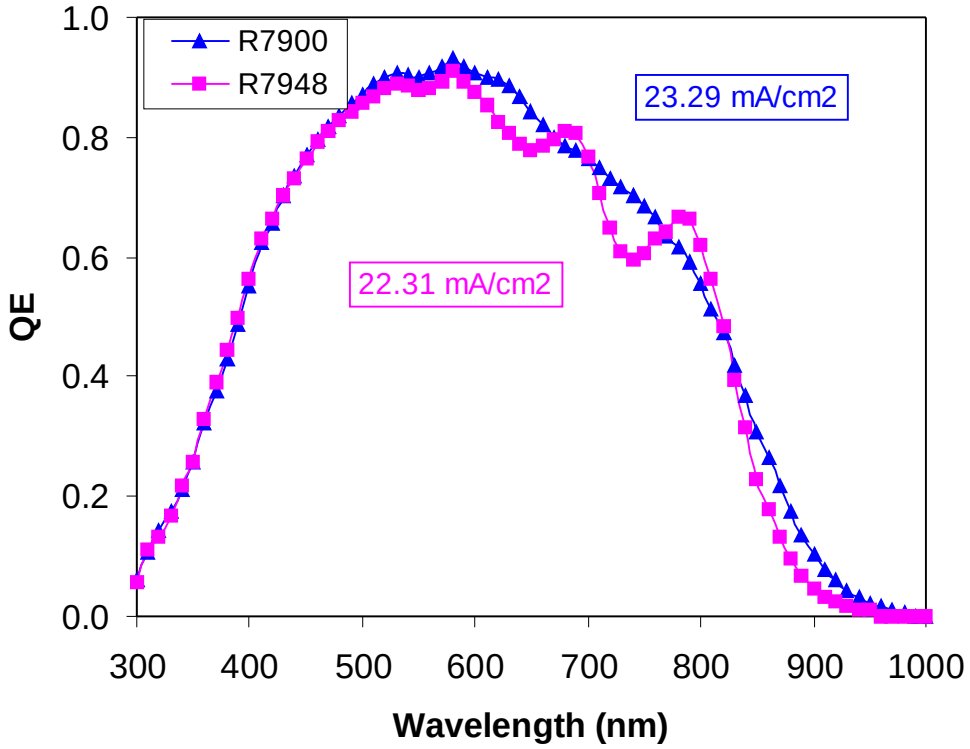
Sample #	BR #	Etching (sec)	RMS (nm)	P_{max} (mW/cm^2)	J_{sc} (mA/cm^2)	V_{oc} (V)	FF
B8564	5BR1748	0	38.2	4.07	10.16	0.641	0.625
R8539	R7749	0	65.3	4.57	11.03	0.650	0.638
R8534	R7900	0	80.5	4.38	10.06	0.654	0.665
R8538	R7753	0	80.7	4.47	11.10	0.651	0.612
R8549	R7753	10	108.5	4.58	10.83	0.655	0.646
B8563	R7948	0	39.6	3.65	9.71	0.627	0.608
B8556	R7948	20	61.1	4.34	10.75	0.637	0.633
B8554	R7948	30	63.2	4.01	10.49	0.623	0.614
B8535	R7943	0	54.8	4.20	10.49	0.635	0.631
B8553	R7943	10	74.0	4.56	10.99	0.651	0.638
B8552	R7943	30	80.0	4.25	10.21	0.651	0.640





J_{sc} and V_{oc} of a-SiGe:H bottom cells versus RMS on the Ag/ZnO.

The measurements were done under AM1.5 solar simulator with an 630-nm long pass filter.

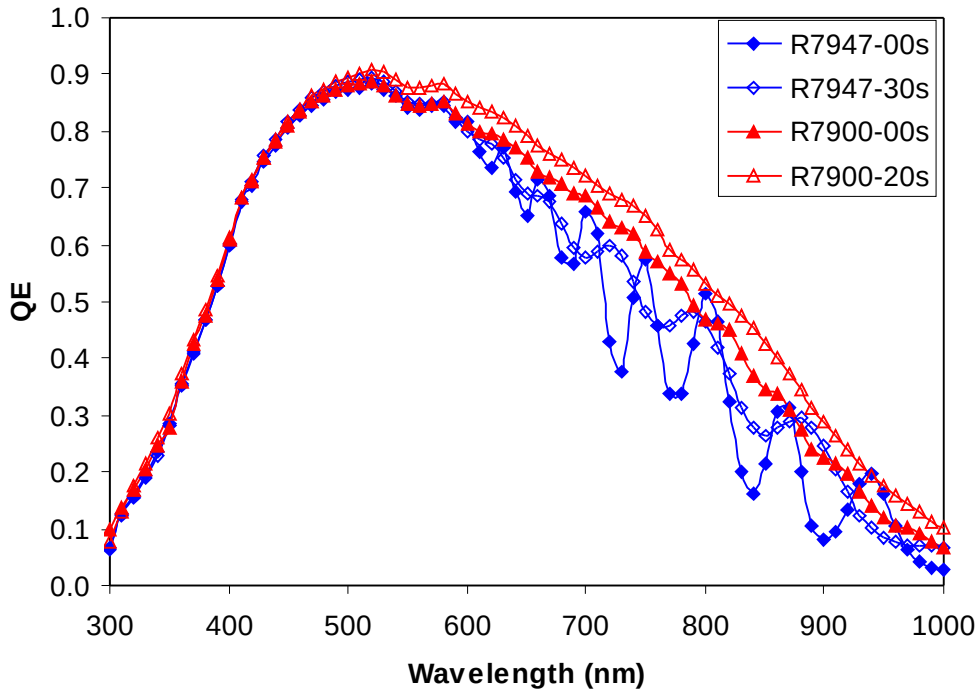


QE curves of two a-SiGe:H cells. One is on a Ag/ZnO BR (R7900) with small features and the other with larger features (R7948).

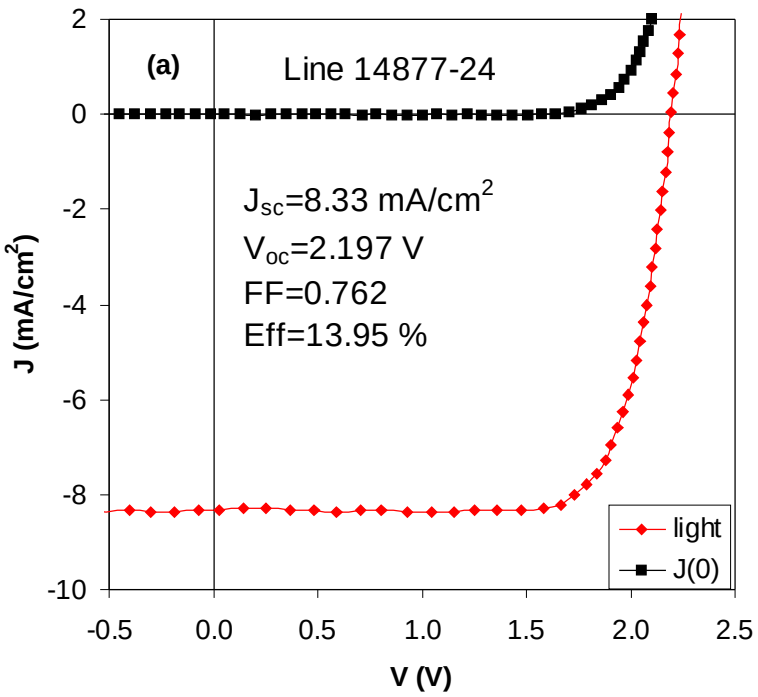
nc-Si:H solar cells

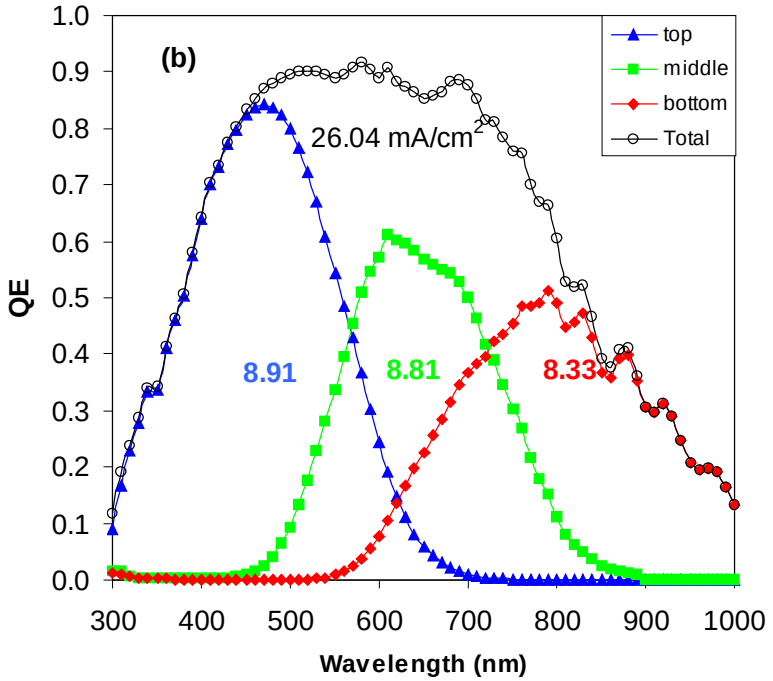
Table II. BR properties and nc-Si:H solar cell performance. The J-V characteristics were measured under an AM1.5 solar simulator with J_{sc} obtained from QE.

Sample #	BR #	Etching (sec)	RMS (nm)	P_{max} (mW/cm^2)	J_{sc} (mA/cm^2)	V_{oc} (V)	FF
L15204	**R7947**	**0**	**33.3**	**5.87**	**20.52**	**0.485**	**0.590**
L15203	**R7947**	**30**	**62.2**	**7.32**	**21.48**	**0.500**	**0.682**
L15201	**R7900**	**0**	**80.5**	**7.06**	**22.62**	**0.480**	**0.650**
L15196	**R7900**	**20**	**107.3**	**7.10**	**24.10**	**0.483**	**0.610**

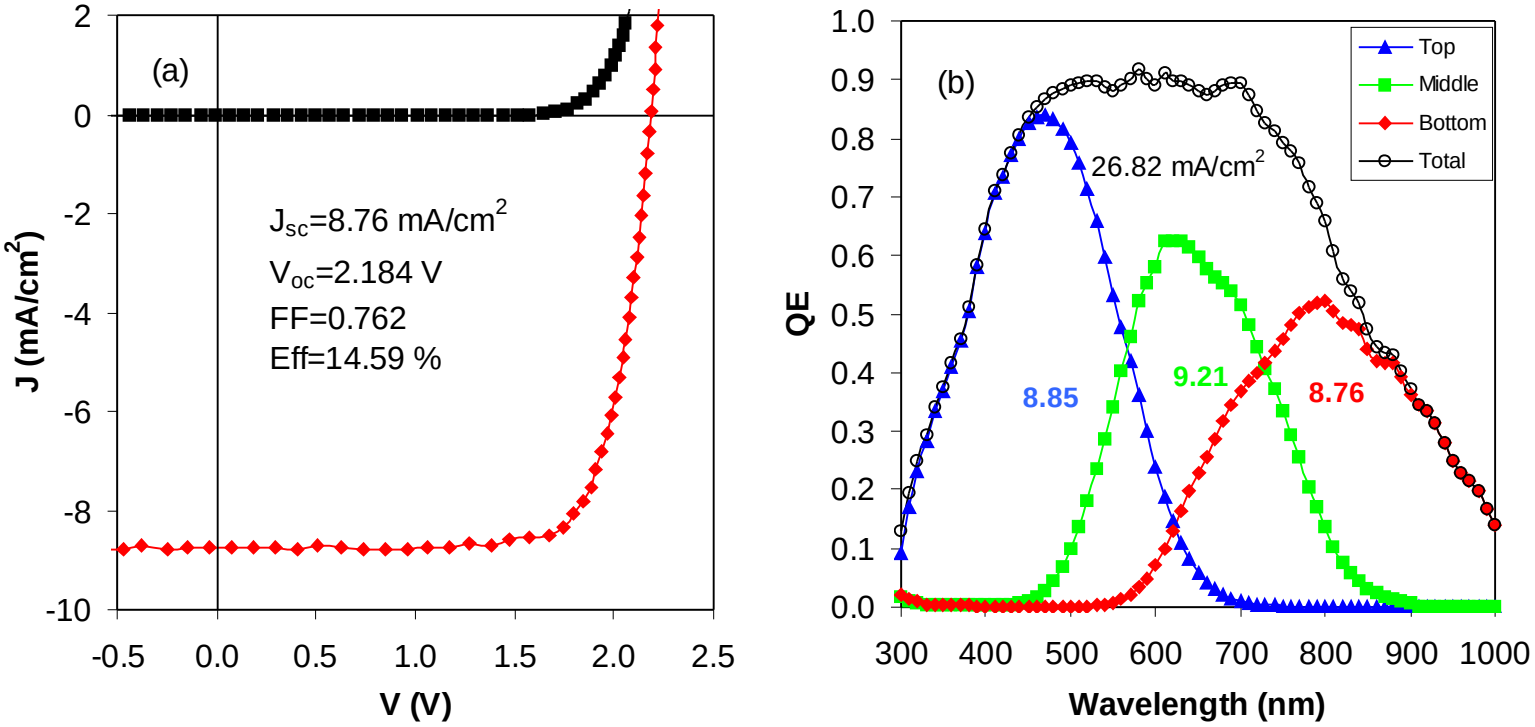


QE curves of four nc-Si:H cells on two Ag/ZnO BRs (R7947, R7900) before and after chemical etching with HCl.





(a) J-V characteristics and (b) quantum efficiency of an a-Si:H/a-SiGe:H/nc-Si:H triple-junction solar cell on conventional Ag/ZnO BR with smaller micro-features.



(a) J-V characteristics and (b) quantum efficiency of an a-Si:H/a-SiGe:H/nc-Si:H triple-junction solar cell on a Ag/ZnO BR with larger micro-features.

SUMMARY

1. The micro-feature size on Ag/ZnO BR can be controlled by either adjusting the deposition condition or subsequent chemical etching process.
2. The RMS measured by AFM varies from 30 to 120 nm.
3. For a-SiGe:H, the improved Ag/ZnO BRs with large micro-features result in an enhanced V_{oc}. We believe that the increase in the micro-feature size reduces the density of the sharp peaks on the BR surface and consequently could reduce the back diffusion of photo-generated carriers at the *n/i* and *i/p* interfaces and the shunt current density.
4. For nc-Si:H solar cells, a clear gain in the J_{sc} has been observed by increasing the micro-feature size on the BR surface, which is due to the effective light trapping by optimizing surface morphology on the BR.
5. We also deposited a-Si:H/a-SiGe:H/nc-Si:H triple-junction cells on the optimized Ag/ZnO BR and achieved a high initial active-area efficiency of 14.6%.

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